



OVERVIEW OF TERRA AND AQUA MODIS STATUS AND TRENDS

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MODIS Science Team Meeting
July 13-15, 2004
Baltimore Airport Marriott Hotel



OUTLINE



- **MODIS BACKGROUND AND STATUS**

- **MODIS FUTURE OBJECTIVES AND TRENDS**



**LAUNCH OF TERRA AND AQUA MISSIONS WERE SUCCESSFUL
AND SPACECRAFT SYSTEMS ARE WORKING WELL
(over 4 years for Terra and 2 years for Aqua)**



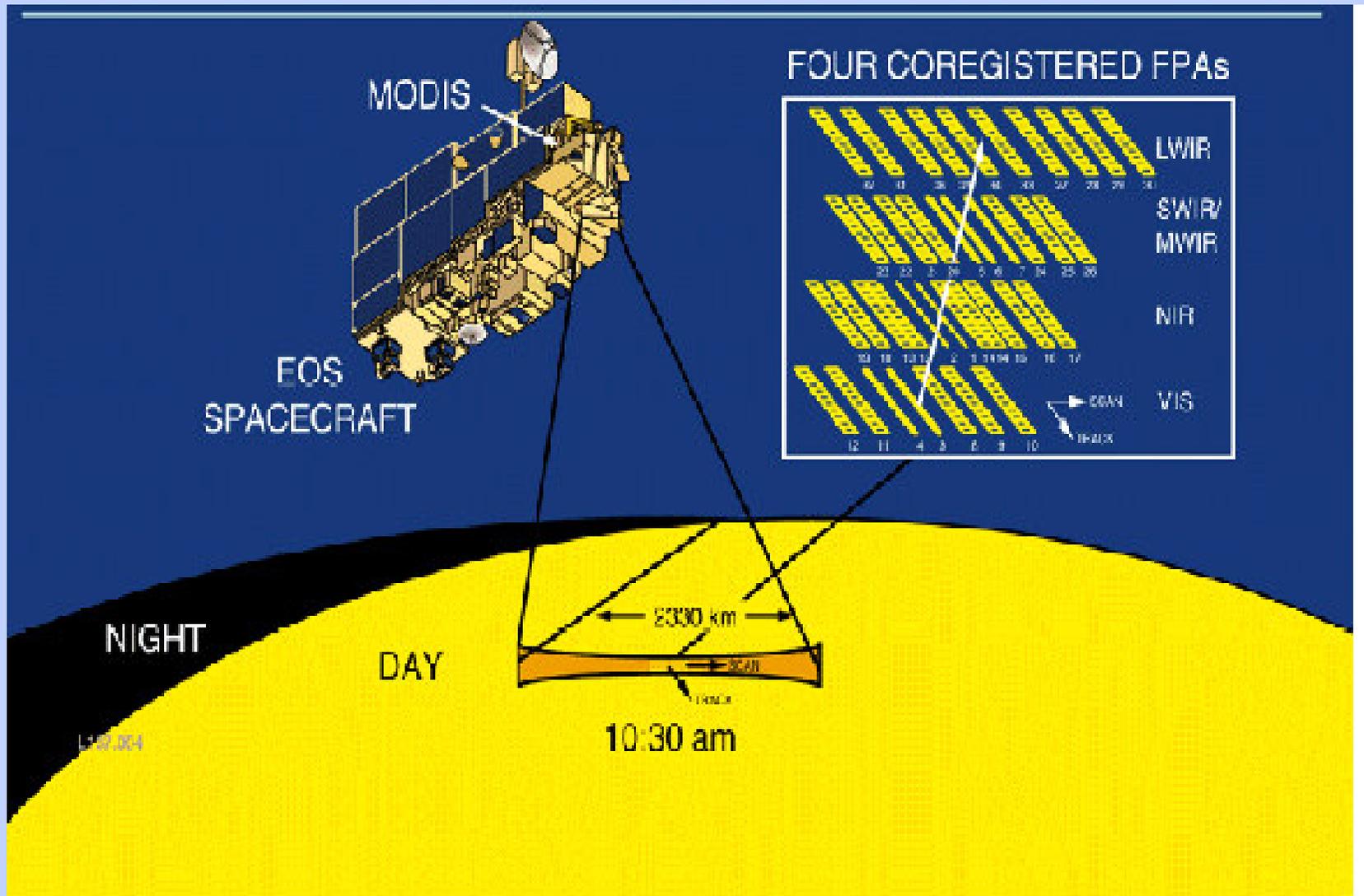
**Terra Launch: Dec. 18, 1999
First Image: Feb. 24, 2000**



**Aqua Launch: May 04, 2002
First Image: June 26, 2002**



Terra and Aqua MODIS Instruments are producing good scientific products





MODIS Key Specifications

(MODIS Instruments are meeting specs)



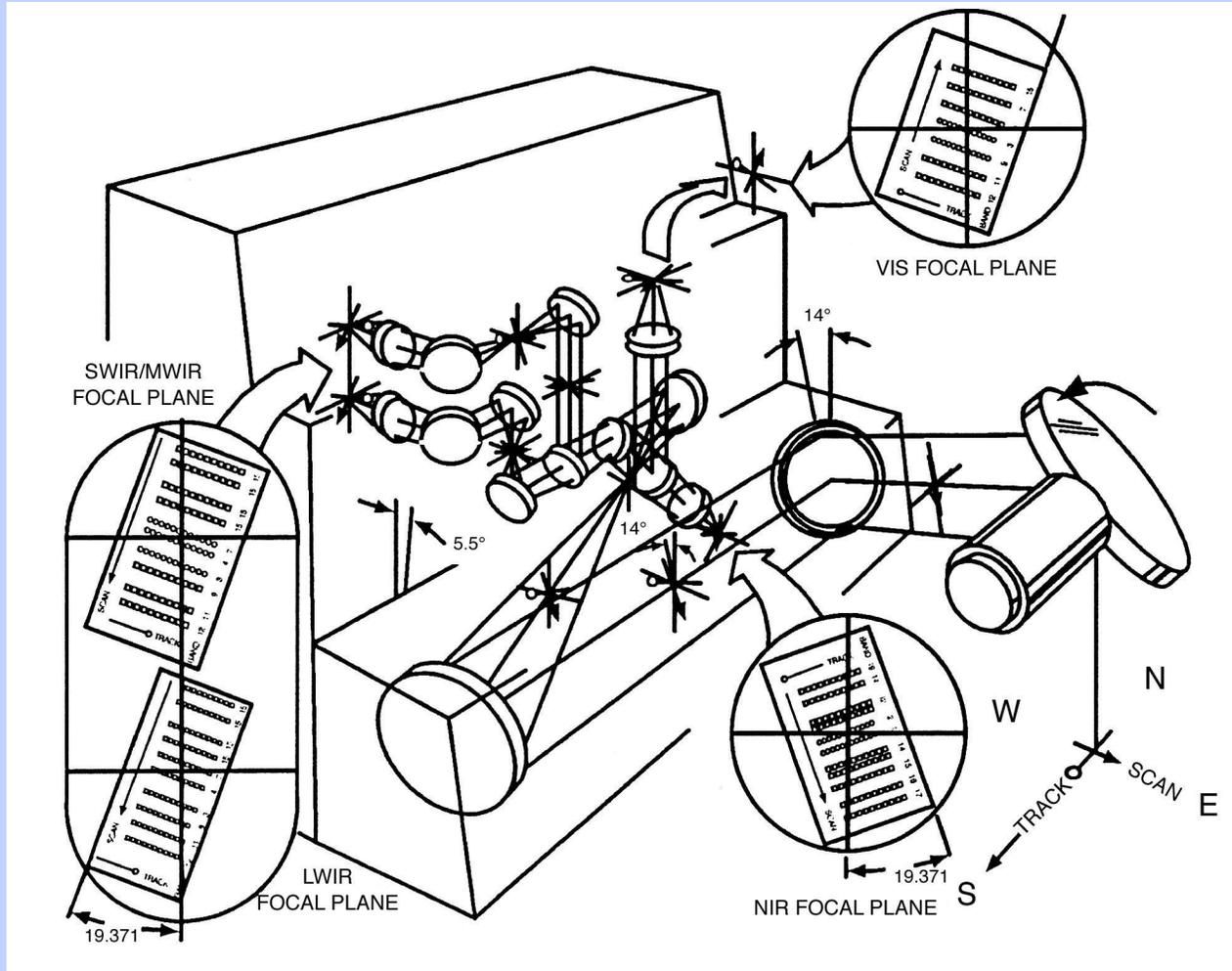
Orbit: 705 km, 10:30 a.m. descending node or 1:30 p.m. ascending node, sun-synchronous, near-polar, circular
 Scan Rate: 20.3 rpm, cross track
 Swath Dimensions: 2330 km (across track) by 10 km (along track at nadir)
 Telescope: 17.78 cm diam. off-axis, afocal (collimated), with intermediate field stop
 Size: 1.0 x 1.6 x 1.0 m
 Weight: 250 kg
 Power: 225 W (orbital average)
 Data Rate: 11 Mbps (peak daytime)
 Quantization: 12 bits
 Spatial Resolution: 250 m (bands 1-2)
 (at nadir): 500 m (bands 3-7), 1000 m (bands 8-36)
 Design Life: 5 years

Primary Use	Band	Bandwidth ¹	Spectral Radiance ²	Required SNR ³	Primary Use	Band	Bandwidth ¹	Spectral Radiance ²	Required NEΔT(K) ³
Land/Cloud Boundaries	1	620-670	21.8	128	Surface/Cloud	20	3.660-3.840	0.45	0.05
	2	841-876	24.7	201	Temperature	21	3.929-3.989	2.38	2.00
Land/Cloud Properties	3	459-479	35.3	243		22	3.929-3.989	0.67	0.07
	4	545-565	29.0	228		23	4.020-4.080	0.79	0.07
	5	1230-1250	5.4	74	Atmospheric	24	4.433-4.498	0.17	0.25
	6	1628-1652	7.3	275	Temperature	25	4.482-4.549	0.59	0.25
	7	2105-2155	1.0	110	Cirrus Clouds	26	1.360-1.390	6.00	150 ⁴
Ocean color/ Phytoplankton/ Biogeochemistry	8	405-420	44.9	880	Water Vapor	27	6.535-6.895	1.16	0.25
	9	438-448	41.9	838		28	7.175-7.475	2.18	0.25
	10	483-493	32.1	802		29	8.400-8.700	9.58	0.05
	11	526-536	27.9	754	Ozone	30	9.580-9.880	3.69	0.25
	12	546-556	21.0	750	Surface/Cloud	31	10.780-11.280	9.55	0.05
	13	662-672	9.5	910	Temperature	32	11.770-12.270	8.94	0.05
	14	673-683	8.7	1087	Cloud Top	33	13.185-13.485	4.52	0.25
	15	743-753	10.2	586	Altitude	34	13.485-13.785	3.76	0.25
	16	862-877	6.2	516		35	13.785-14.085	3.11	0.25
Atmospheric	17	890-920	10.0	167		36	14.085-14.385	2.08	0.35
Water Vapor	18	931-941	3.6	57	¹ Bands 1 to 19, nm; Bands 20-36, μm ² (W/m ² -μm-sr) ³ SNR=Signal-to-noise ratio NEΔT=Noise-equivalent temperature difference } Performance goal is 30%-40% better than required ⁴ SNR				
	19	915-965	15.0	250					



MODIS OPTICAL SYSTEM

SPACECRAFT SYSTEMS AND INSTRUMENT PERFORMANCE LEAD TO WELL GEOLOCATED PRODUCTS

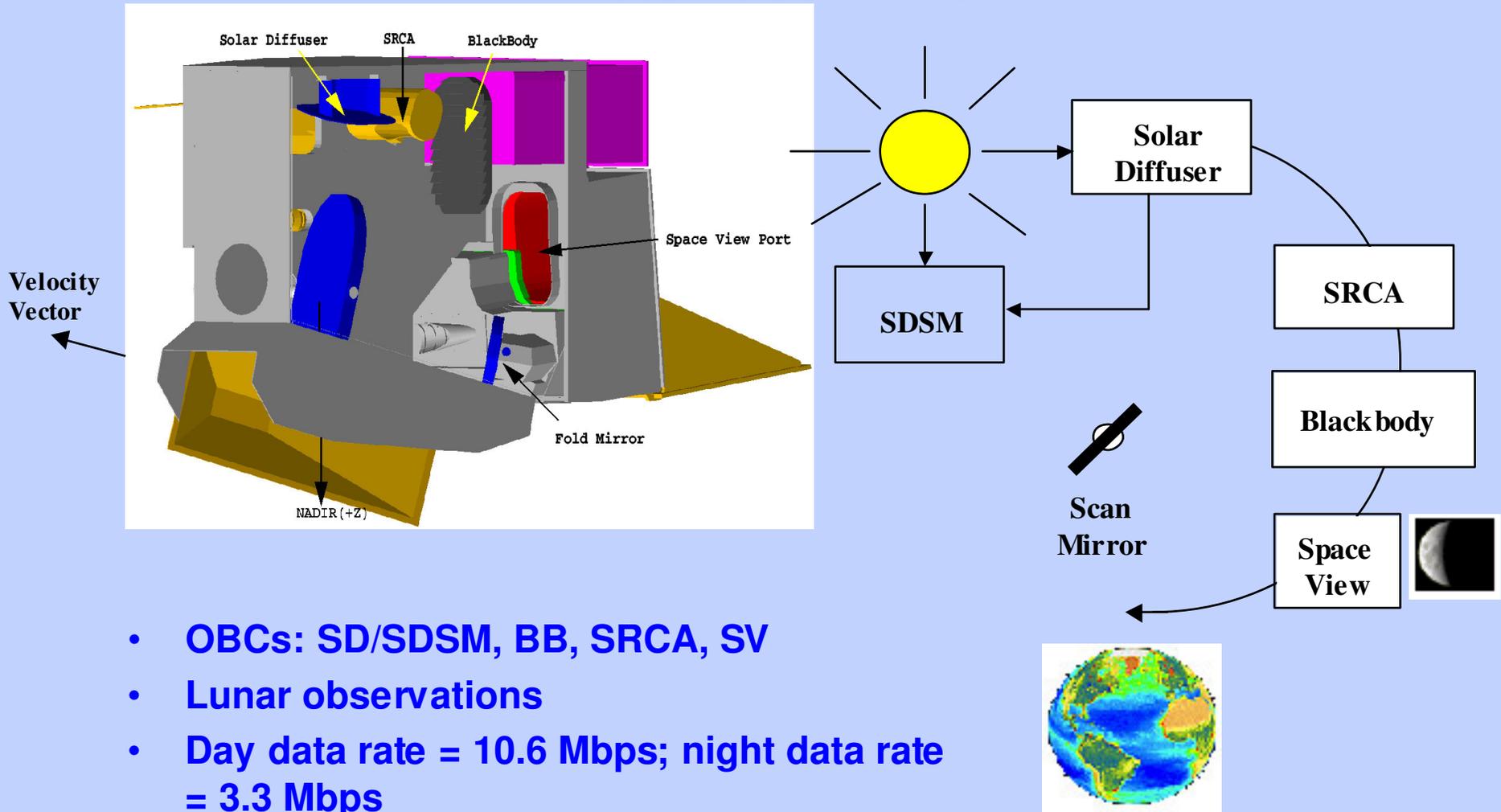




MODIS On-orbit Calibration and Characterization



MODIS INSTRUMENTS ARE WELL CALIBRATED AND CHARACTERIZED
ALTHOUGH LOTS OF WORK CONTINUING



- OBCs: SD/SDSM, BB, SRCA, SV
- Lunar observations
- Day data rate = 10.6 Mbps; night data rate = 3.3 Mbps



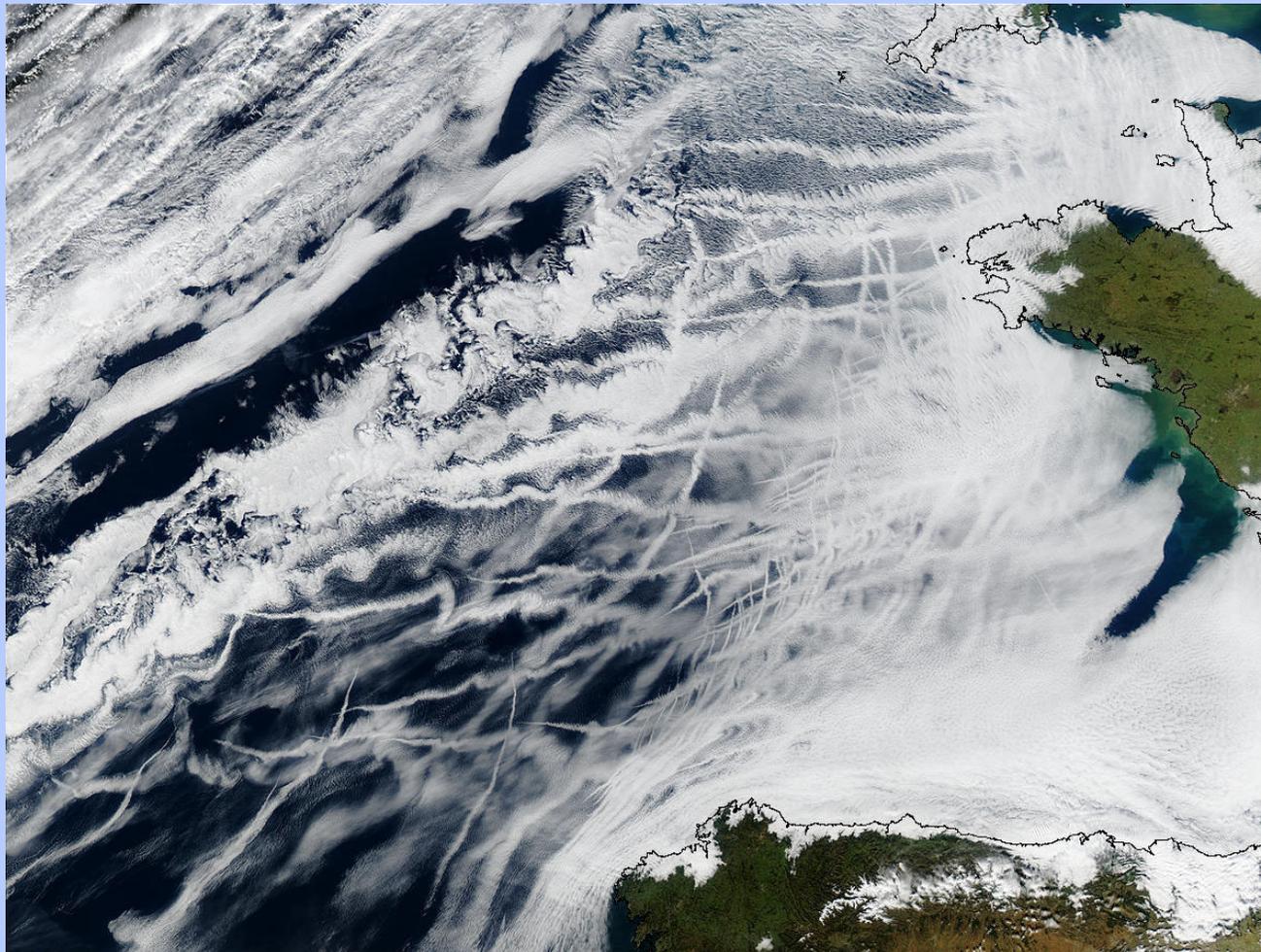
Aqua/MODIS Level-1B Image

(M. D. King, S. Platnick et al. - NASA GSFC)



R = 0.65 μm
G = 0.56 μm
B = 0.47 μm

January 27, 2003
1340 UTC



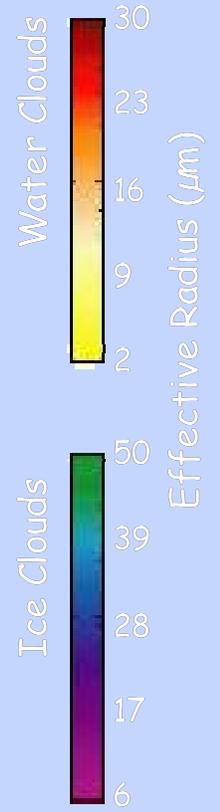
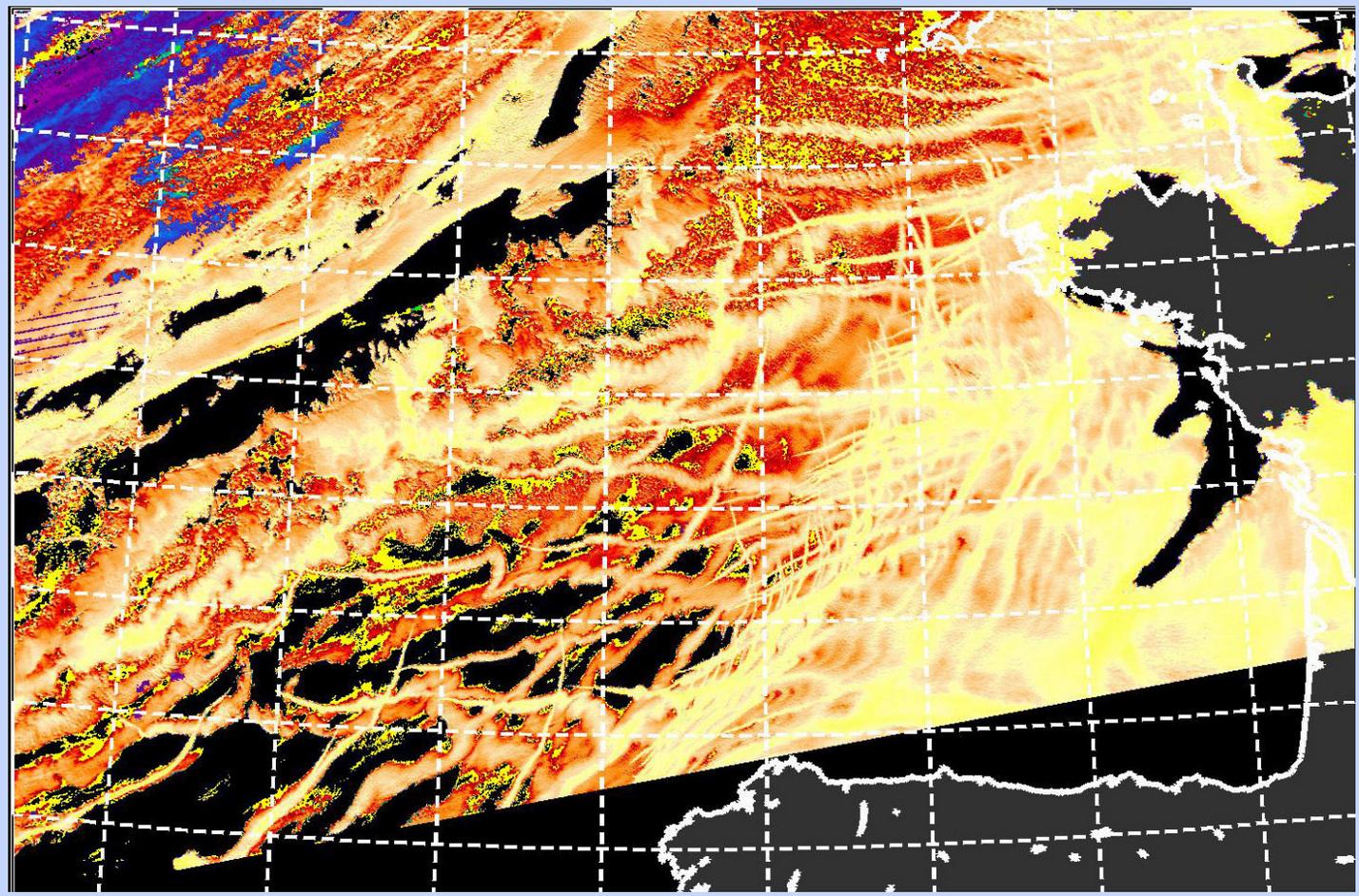


Aqua/MODIS Cloud Effective Radius

(M. D. King, S. Platnick et al. - NASA GSFC)

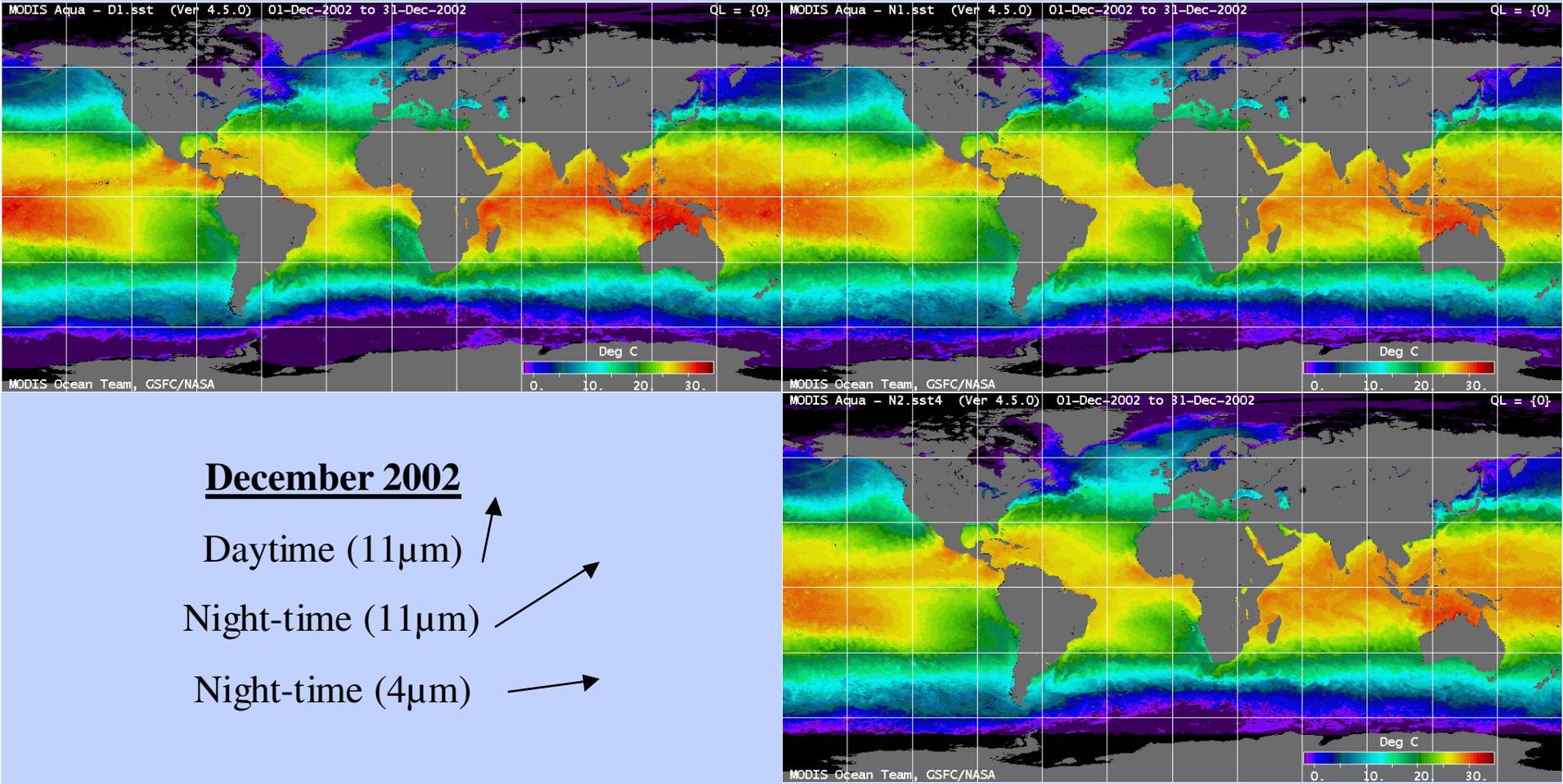


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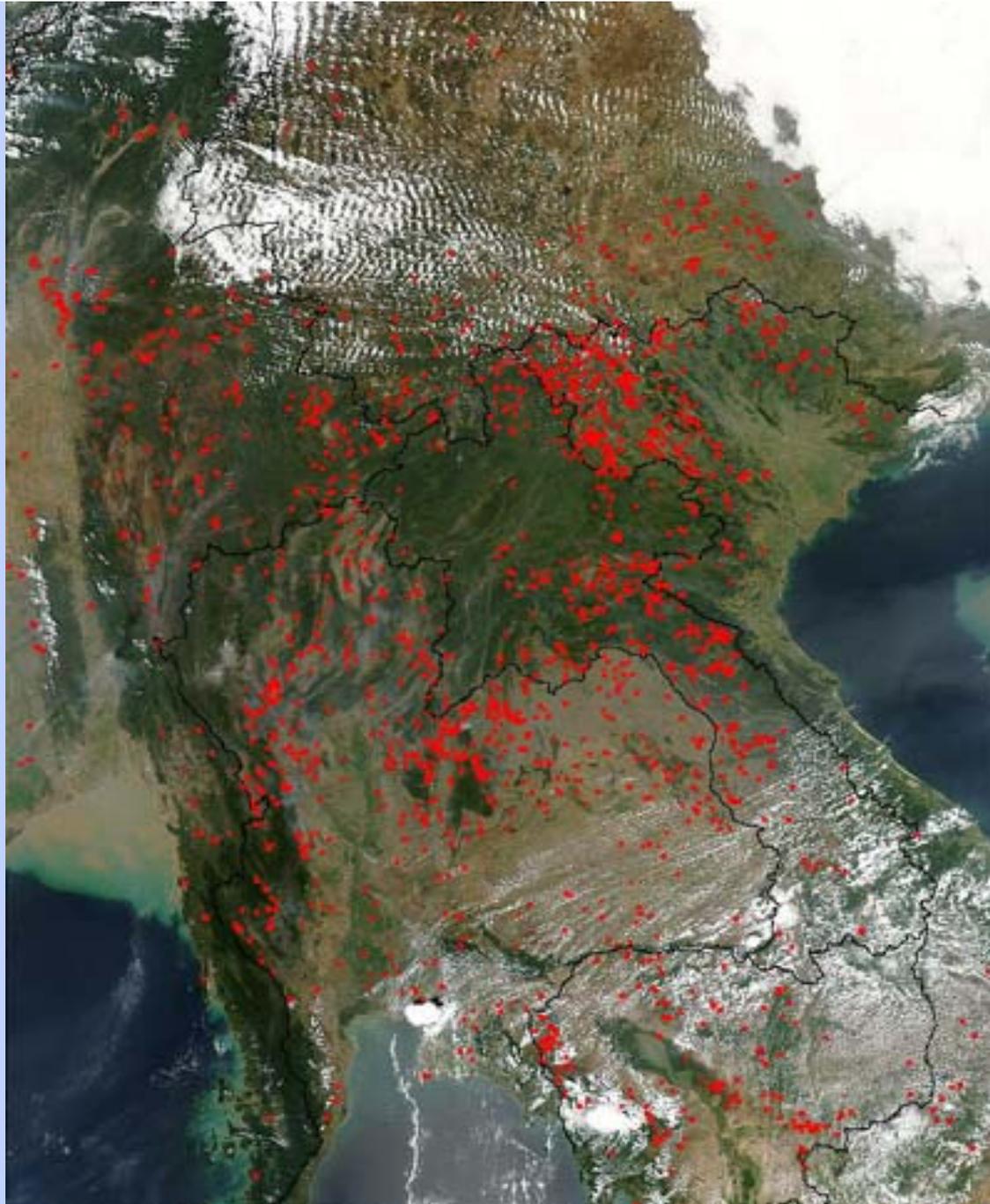


MODIS SST fields (P. Minnett/U. of Miami)



December 2002

- Daytime (11 μ m) \nearrow
- Night-time (11 μ m) \nearrow
- Night-time (4 μ m) \rightarrow



MODIS Rapid Response

**MODIS Fire
Detections
SE Asia
04/03/03**

(Descloîtres et al)



Present EOS DR Ingest Sites (P. Coronado/GSFC)



- 82 Ingest sites around the world for Terra/Aqua DB downlink
- Over 900 Users of data extending from 82 ingest sites
- List is located on the Direct Readout Portal



Who's in the Current Direct Broadcast Community (P. Coronado/GSFC)



- **There are currently 82 verifiable EOS X-band receiving ground stations world-wide relying on Direct Broadcast, including 6 stations from EOS science team members.**
- **There is a community of over 900 members.**
 - **Representing 27 science research organizations doing DB land, ocean and atmospheric processing.**
 - **53 companies that base their application algorithms and value added products on DB data.**



Direct Readout (DR) Portal Software Downloads and Questions (P. Coronado/GSFC)



Software Date First	Number of Downloads	Number of Questions	Number of Help Requests	Staged
• RT-STPS	280	40	21	1/29/2002
• GBAD	188	24	14	8/28/2002
• Simulcast	110	5	2	5/07/2003
• Sorcerer	79			4/28/2003
• MODIS Band Extractor	78	1		1/15/2003
• Construction Record Lister	43			4/21/2003
• MODIS Band Viewer	69			1/22/2003
• DB Fire (MOD14)	156	10	8	1/24/2002
• GSFC DAAC Level 1	185	30	5	6/27/2002
• DB NDVI	179		3	
• MAP-I	35			
• SDP Toolkit	22			
• PGE 1-82	2010	85	300	7/31/2002- 7/01/2003

There are 947 registered users on the NASA DR Portal



SOME OTHER MODIS “INDICES” OF ACCOMPLISHMENT



•PUBLICATIONS

-Overall in MODIS/MODARCH Data base: Total of 1423 unique publications from 1990 to the present (but 2003 and 2004 are not complete)

-Fall AGU Abstracts “index”:

03-170, 02-82, 01-82, 00-52, 99-16, 98-12, 97-7, 96-5, 95-8

-ISI Web of Science “index” (1959 to Present):

04-84, 03-136, 02-83, 01-49, 00-46, 99-46,

98-29, 97-26, 96-17, 95-9, 94-11, 93-3, 92-8, 91-6, 90-0, 89-2

Total= 557 refereed publications

-ISI Proceedings “index” (1990-present):

Total= 499 publications

•GRADUATE STUDENT SUPPORT (as of early 2003):

174 total; 89 PhD, 60 MS, 25 MA

•WORKSHOPS: several successes for land, ocean, atmosphere, cal/val



FUTURE TRENDS SIGNIFICANT TO MODIS



MODIS SCIENCE TEAM HAD 28 MEMBERS; NOW IT HAS 90!

-27 “Refinement/Maintenance” of products P.I.’s

-63 “Science” P.I.’s

All need to work together to meet the goals and objective of the NASA Earth Science Program

-as such the Science Team will hopefully be willing and able to be a useful and effective microcosm of the broader science, and applications, communities regarding improving MODIS products and related services



OVERALL MODIS SCIENCE TEAM THRUSTS

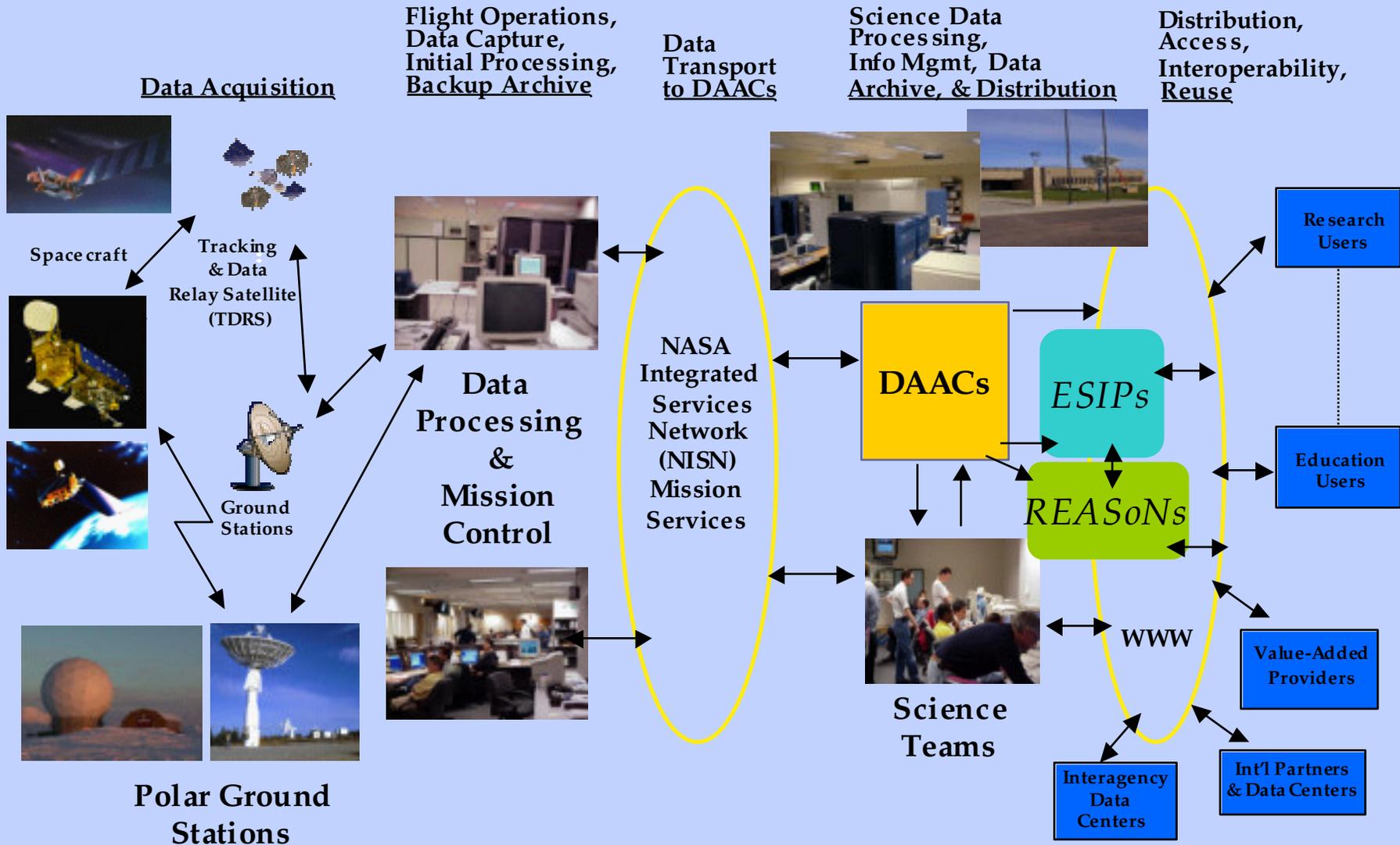


- Support and collaborate with the relevant parts of the Earth Observing System Data and Information Service (EOSDIS) or other entities pursuing the provision and use of MODIS data products to the general science and applications communities or the public at-large so as to **improve access to and use of MODIS data products**
- Pursue the programmatically necessary goal of **providing climate-data-record quality data sets of MODIS products**. The characteristics or requirements for these data sets will be those obtained from the science community via procedures approved, prescribed or represented by NASA Headquarters Office of Earth Science program management
- Interact with the modeling community(ies) to **facilitate and expedite the assimilation of MODIS data products into such Earth system and Earth system component models**. These models can include everything from global earth systems processes and trends to regional and local scale models simulations as well as applications specific to resource management and decision models support needs
- **Pursue interdisciplinary efforts including the use of MODIS products**; i.e. where appropriate ensure that MODIS land products can be employed effectively by atmospheric efforts, MODIS atmosphere products can be used by land and oceans efforts, etc.
- **Educate and train students** to appreciate and be able to use remote-sensing (e.g., MODIS) data for doing Earth science and applications



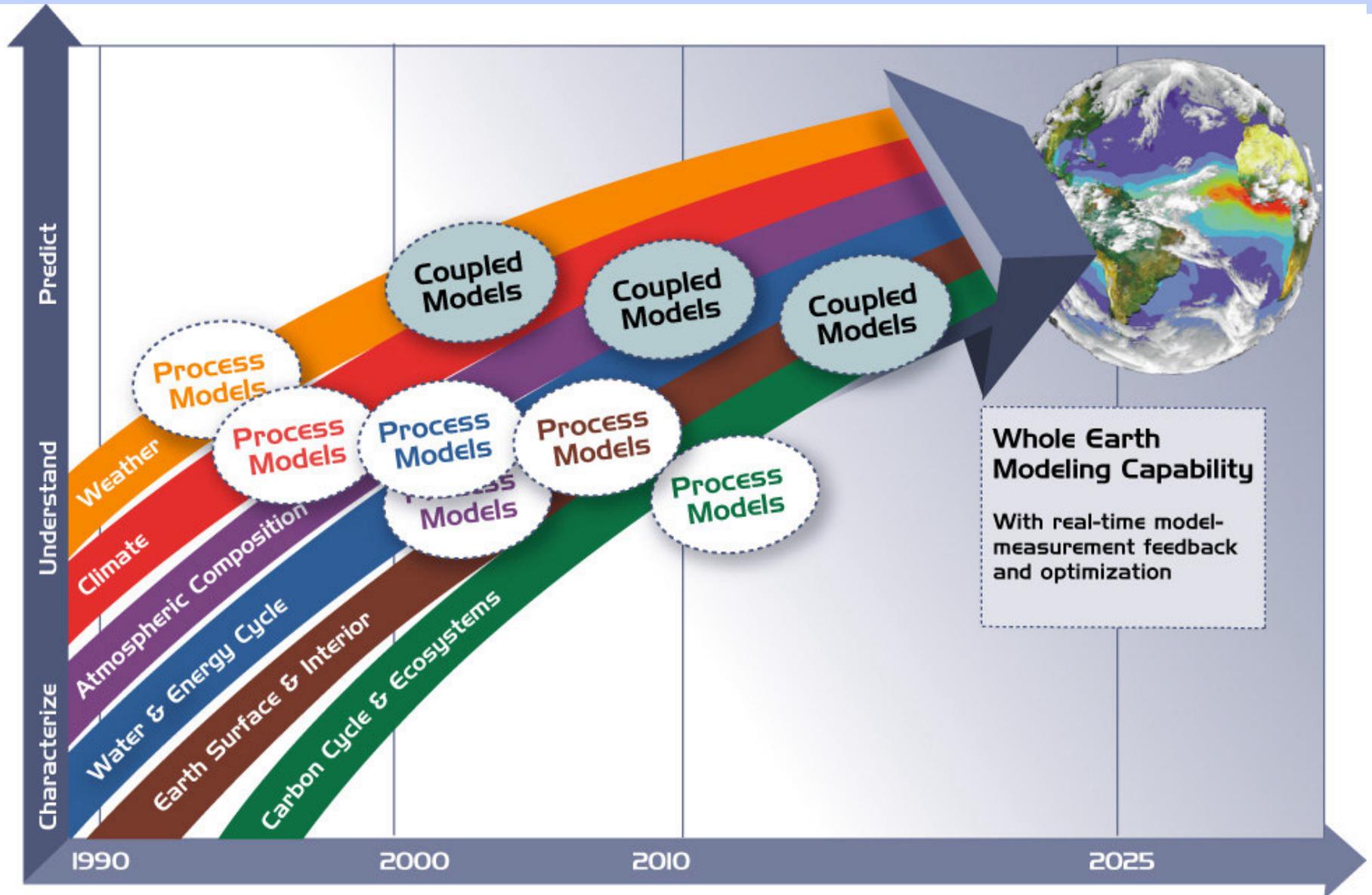
Data System Architecture

- EOSDIS with ESIPs & REASoNs



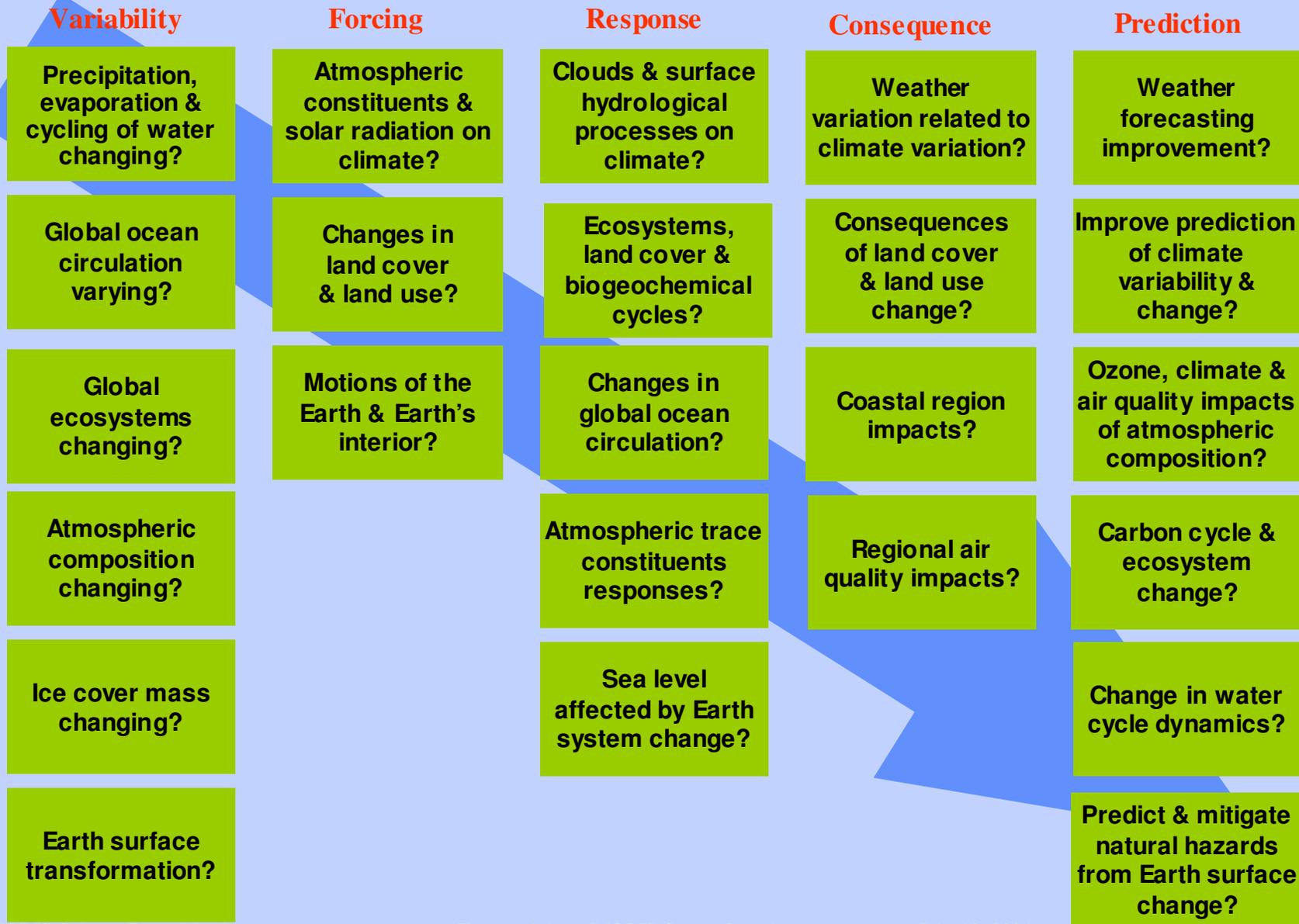


Focus Area Integration via Earth System Modeling





ESE Next Tier Science Questions



Carbon Cycle and Ecosystems

Knowledge Base

Human-Ecosystems-Climate Interactions (Coupling, Model-Data Fusion, Assimilation)

Funded

Unfunded

Partnership

T = Technology development

 = Field Campaign

Report

T

High-Resolution Atmospheric CO₂

Integrated global analyses

Sub-regional sources/sinks

T

Profiles of Ocean Particles

Carbon export to deep ocean

T

Physiology & Functional Groups

Models w/improved ecosystem functions



Southern Ocean Carbon Program

Process controls identified; errors in sink reduced

T

New Ocean Carbon / Coastal Event Observations

Reduced uncertainties in fluxes and coastal C dynamics

T

Vegetation 3-D Structure, Biomass, & Disturbance

Terrestrial carbon stocks & species habitat characterized

Global CH₄; Wetlands, Flooding & Permafrost

CH₄ sources characterized and quantified

Global Atmospheric CO₂ (OCO)

Regional carbon sources/sinks quantified for planet



N. American Carbon Program

N. America's carbon budget quantified



Land Use Change in Amazonia

Effects of tropical deforestation quantified; uncertainties in tropical carbon source reduced

2002: Global productivity and land cover resolution coarse; Large uncertainties in biomass, fluxes, disturbance, and coastal events

Improvements:

Case Studies

Process Understanding

Models & Computing Capacity

Land Cover (Landsat)

Land Cover (LDCM)

Land Cover (LDCM II)

Ocean Color (SeaWiFS, MODIS)

Systematic Observations

Vegetation, Fire (AVHRR, MODIS)

Ocean Color/Vegetation (VIIRS/NPP)

Ocean/Land (VIIRS/NPOESS)

2002

2004

2006

IPCC

2008

2010

IPCC

2012

2014

2015

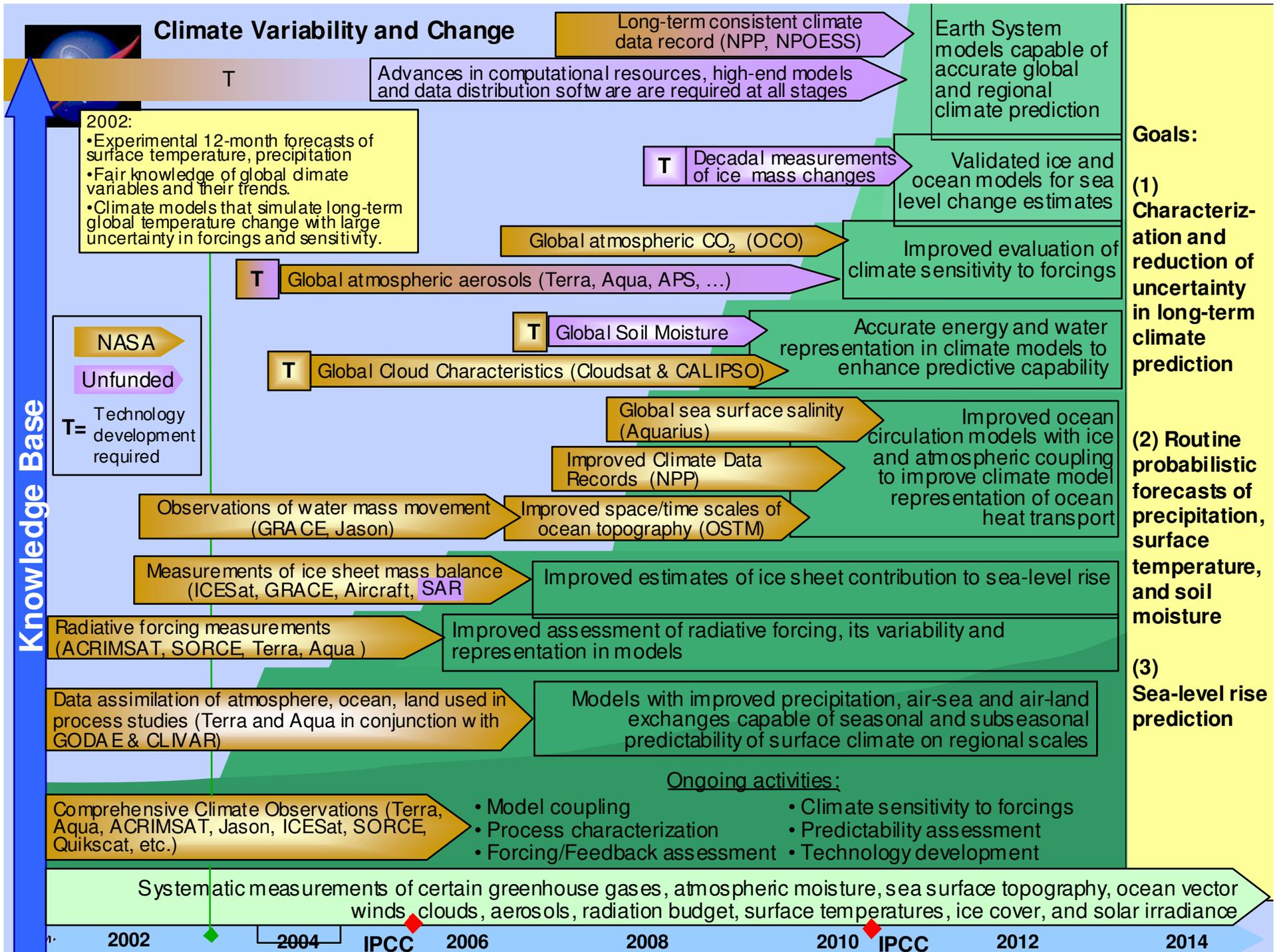
NA Carbon

NA Carbon

Global C Cycle

Global C Cycle

Goals: Global productivity and land cover change at fine resolution; biomass and carbon fluxes quantified; useful ecological forecasts and improved climate change projections



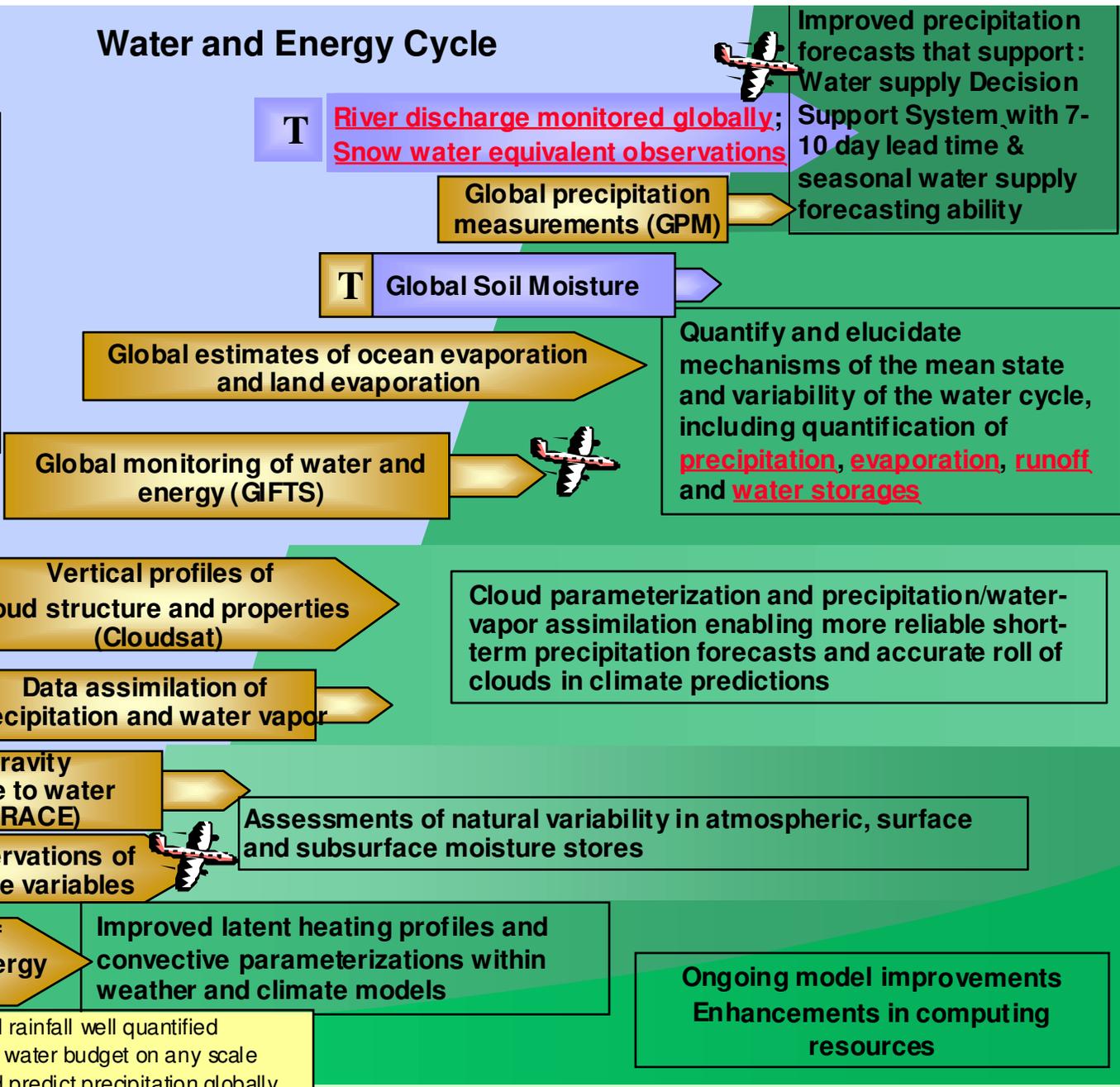
Water and Energy Cycle

Knowledge Base



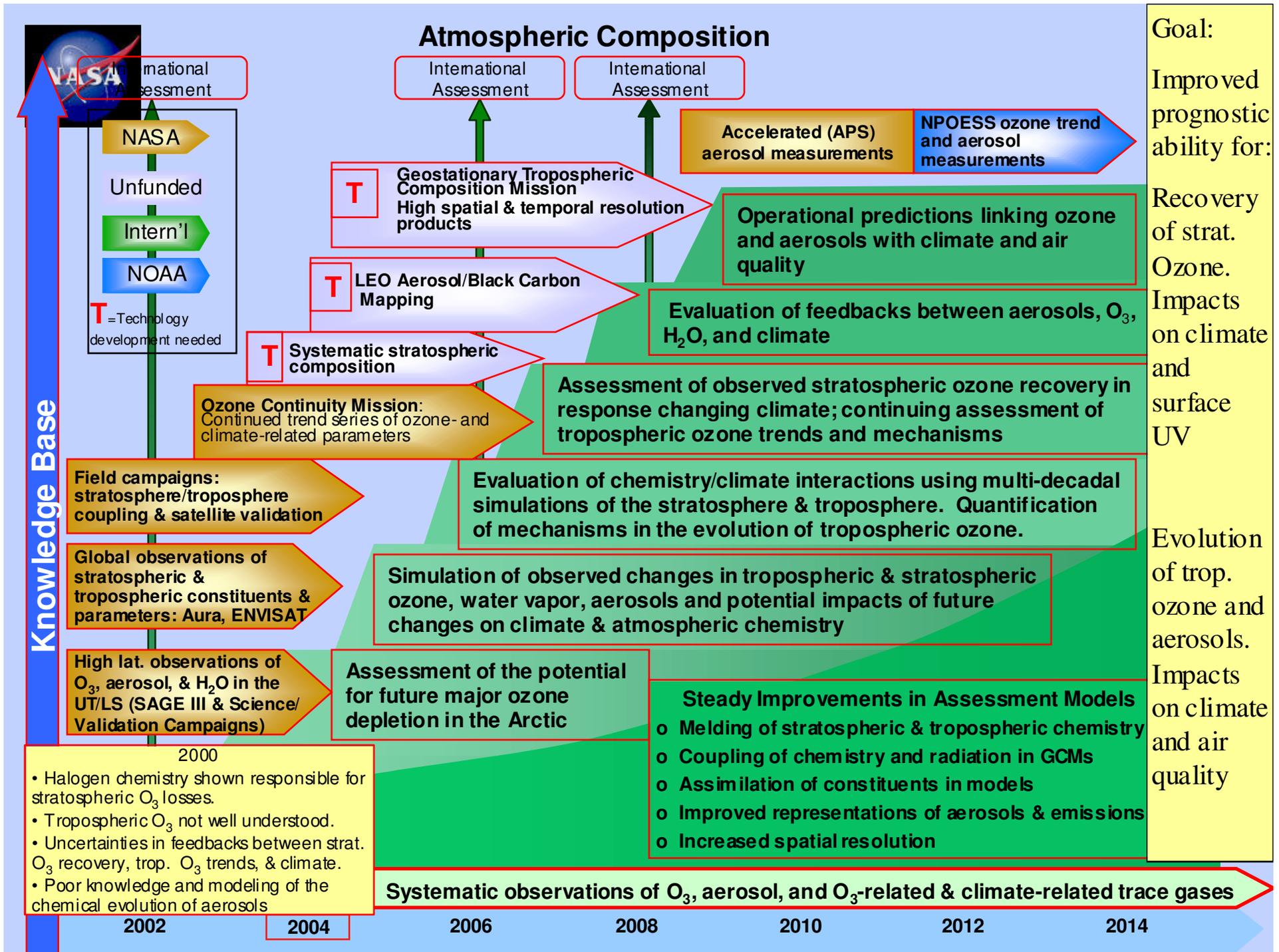
- NASA →
- Joint →
- Unfunded →

= field campaign
T = Technology development required



GOAL: Models capable of predicting the water cycle, including floods and droughts, down to 10s of kms

2002 2004 2006 IPCC Report 2008 2010 IPCC Report 2012 2014 2015





MODIS Products as of late 2003; tbd in future



Terra/MYD for Aqua)

- MOD01** Level-1A Radiance Counts
- MOD02** Level-1B Calibrated Relocated Radiances
 - also Level 1B “subsampled” 5kmX5km pro
- MOD03** Geolocation Data Set
- MOD04** Aerosol Product
- MOD05** Total Precipitable Water
- MOD06** Cloud Product
- MOD07** Atmospheric Profiles
- MOD08** Gridded Atmospheric Product (Level 3)
- MOD09** Atmospherically-corrected Surface Reflectance
- MOD10** Snow Cover
- MOD11** Land Surface Temperature & Emissivity
- MOD12** Land Cover/Land Cover Change
- MOD13** Vegetation Indices
- MOD14** Thermal Anomalies, Fires & Biomass Burning
- MOD15** Leaf Area Index & FPAR
- MOD16** Surface Resistance & Evapotranspiration
- MOD17** Vegetation Production, Net Primary Productivity
- MOD18** Normalized Water-leaving Radiance
- MOD19** Pigment Concentration
- MOD20** Chlorophyll Fluorescence
- MOD21** Chlorophyll_a Pigment Concentration
- MOD22** Photosynthetically Active Radiation (PAR)
- MOD23** Suspended-Solids Conc, Ocean Water
- MOD24** Organic Matter Concentration
- MOD25** Coccolith Concentration
- MOD26** Ocean Water Attenuation Coefficient
- MOD27** Ocean Primary Productivity
- MOD28** Sea Surface Temperature
- MOD29** Sea Ice Cover
- MOD30** Temperature and Moisture Profiles
- MOD32** Processing Framework & Match-up Database
- MOD33** Gridded Snow Cover
- MOD34** Gridded Vegetation Indices
- MOD35** Cloud Mask
- MOD36** Total Absorption Coefficient
- MOD37** Ocean Aerosol Properties
- MOD39** Clear Water Epsilon
- MOD43** Albedo 16-day L3
- MOD44** Vegetation Cover Conversion



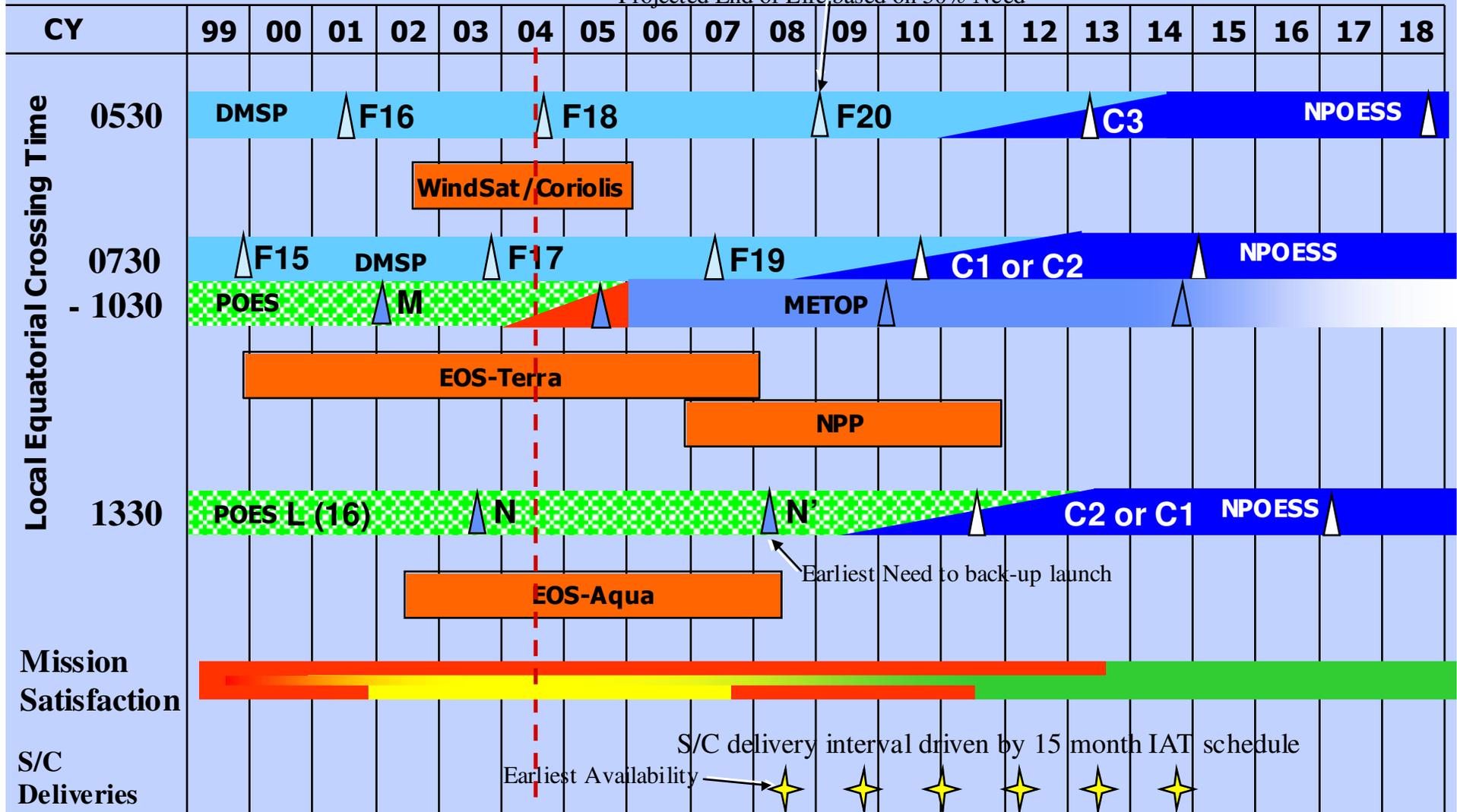
Satellite Transition Schedule

(9 March 2001)

Slopes indicate 10-90% need (NPOESS GAP 5b)



Projected End of Life based on 50% Need

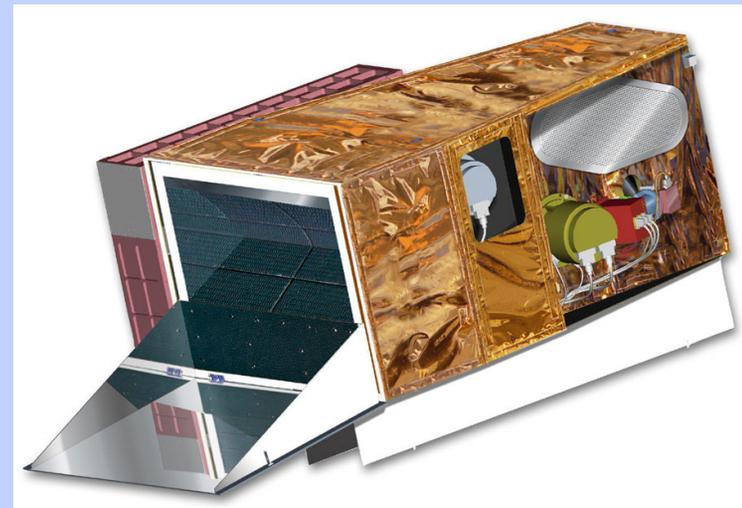




Visible Infrared Imaging Radiometer Suite (VIIRS)



- **Purpose:** Global observations of land, ocean, & atmosphere parameters at high temporal resolution (~ daily)
- **Predecessor Instruments:** AVHRR, OLS, MODIS, SeaWiFS
- **Management:** Integrated Program Office
- **Status:**Phase C/D (Raytheon)
- **Approach:** Multi-spectral scanning radiometer (22 bands between 0.4 μm and 12 μm)
12-bit quantization
- **Swath width:** 3000 km
- **Changes to specifics of band dynamic ranges, bandpasses & band centers being negotiated**
- **Consideration of adding 6.7 micrometer water vapor band to FM2 & later models**





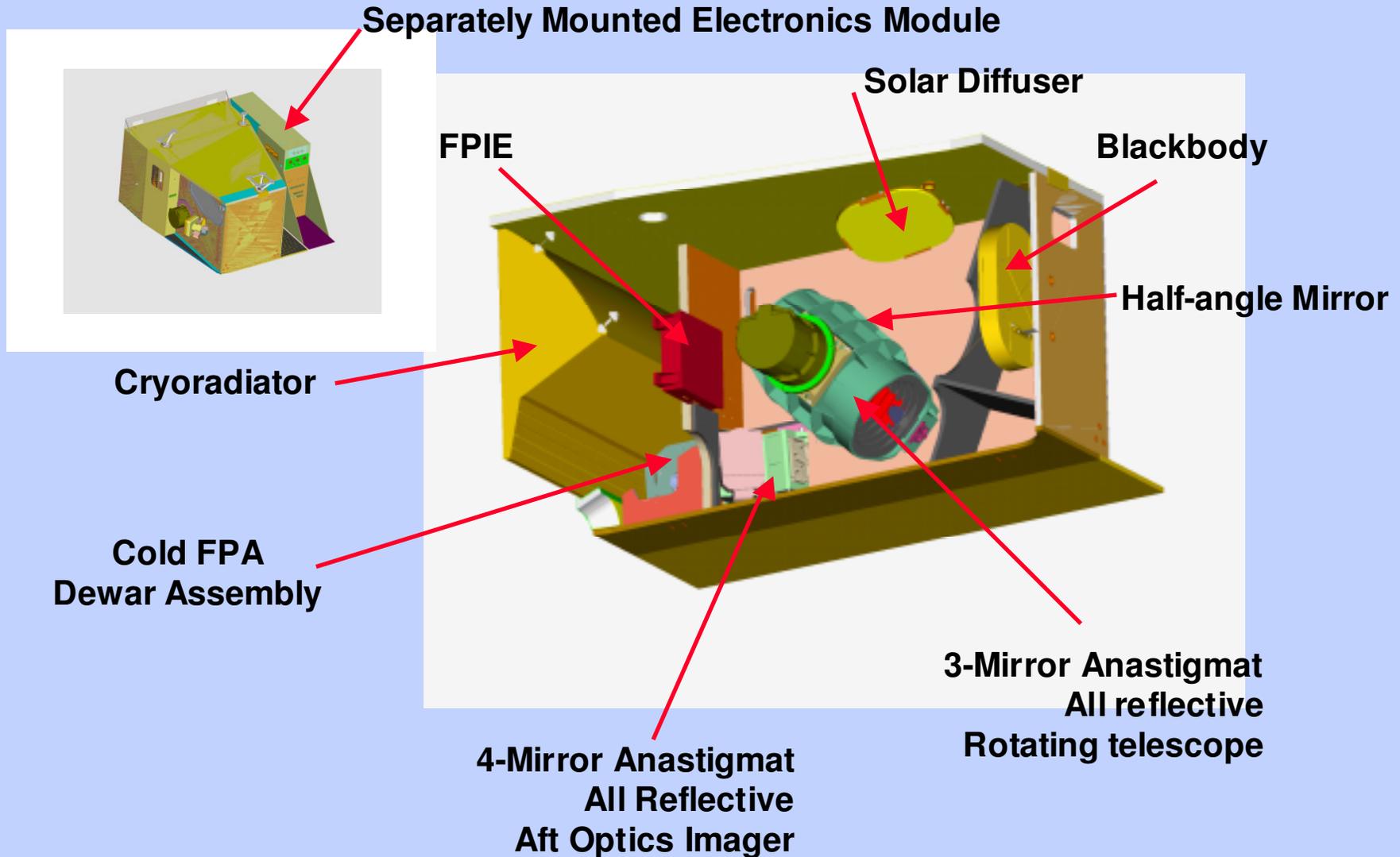
VIIRS Spectral Bands



- 22 Bands
 - Subset of MODIS bands plus day-night panchromatic band
- Two spatial resolutions
 - Imagery resolution bands: 370 m at nadir
 - Moderate resolution bands: 740 m at nadir
- Features
 - 8 (Moderate) or 16 (Imagery) detectors per scan
 - Bands spatially nested
 - Some bands have dual gain
 - Maximize dynamic range without precision penalties
- Constrained pixel growth with scan angle



Visible Infrared Imaging Spectroradiometer (VIIRS)





VIIRS Calibration



- Stray light much better than MODIS
 - Driven by needs of the day-night (DNB)
 - Rotating telescope, extensive baffling reduces scattered light
- V-groove blackbody similar to MODIS
 - Baffled to avoid Earth illumination
 - Emissivity of 0.9998
 - Controlled to 290K by pulsed voltage
 - Heat to 315K
- Solar Diffuser (SD) evolutionary from MODIS
 - 1 time door
 - New design eliminates “ripples”
- Solar Diffuser Stability Monitor (SDSM) evolutionary from MODIS
 - 7 bands
 - Views 70% of SD area
- Planning to use 2nd order polynomial for all bands
- Characterization plan similar to MODIS
- Lunar views possible



CONCLUSIONS

- **SPACECRAFT AND INSTRUMENTS WORKING WELL, BUT FURTHER EFFORT CONTINUING TO CHARACTERIZE SENSOR CALIBRATION/RESPONSE E.G., OCEANS**
- **LOTS OF EXCELLENT SCIENCE/APPLICATIONS RESULTS APPEARING USING MODIS PRODUCTS**
- **NEED TO PURSUE GENERAL THRUSTS MEANT TO ENHANCE USABILITY AND ACCESS TO PRODUCTS BY SCIENCE AND APPLICATIONS COMMUNITIES**
- **PURSUE ACTIVITIES TO FACILITATE MODIS TRANSITION TO NPOESS VIIRS**
- **OVERALL MODIS HAS BEEN A TREMENDOUS SUCCESS AND HOLDS CONSIDERABLE PROMISE FOR EVEN GREATER SUCCESS IN THE FUTURE**